Path 15 Upgrade Cost Analysis Study

California Independent System Operator

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1. Executive Summary

This report provides the results and applied methodologies for analyzing the potential cost savings resulting from upgrading Path15. The focus of the study is to analyze the impact of congestion on three markets. The first is the impact on the energy costs for PX load resources in the PX Day-Ahead (DA) the PX Hour-Ahead (HA) and ISO real-time (RT) energy markets. Secondly, the impact of congestion on the ISO Out-of-Market (OOM) energy costs. And thirdly, the impact of congestion on the DA Ancillary Service (A/S) and HA A/S market costs.

This report concludes, based on the assumptions in the body of the report, that the total additional cost of energy and ancillary services were up to $**221.7** million due to Path 15 congestion from 9/1/99 to 12/31/00.

An important assumption in this analysis is that if Path 15 were upgraded there would be no Path 15 congestion and thus no impact on the energy, OOM and A/S costs. Thus, if an upgrade were made the energy and A/S costs would result from *unconstrained* prices, as well as there would be no need to call OOM energy due to Path 15.

In determining the savings of a Path15 upgrade, unconstrained prices must be produced in an estimated fashion. For energy costs associated with PX load resources, unconstrained market clearing prices are available from the PX for the DA and HA markets. However, for the RT market, unconstrained real-time prices are not available for those hours when the ISO split the Balancing Energy and Ex-Post Price (BEEP) stack due to Path15 real-time congestion. This is also, in general, the case in the A/S markets. Section 6 of this report provided the details on how two different unconstrained prices are produced. In general, the procedure is straightforward in that these two estimated unconstrained prices are (i) the lower of two zonal (SP15 and NP15) prices (this is called the *Low* price) and (ii) 25% of the way between the two zonal prices (this is called the *25%* price). When Path 15 is split, then the ZP26 price is the same as the SP15 price.

Therefore, this procedure provides an estimation of the unconstrained prices. The range of unconstrained prices are calculated and applied within the analysis, thus resulting in a *range* of potential savings to the state of California from a Path 15 upgrade.

Below, the cost results of the analysis for each of the three markets are given. For this analysis, the results are provided in two time periods. One period is from 9/1/99 to 8/31/00 and the period is from 9/1/00 to 12/31/00. First, however, the number of congestion hours for the energy markets and the ancillary services markets are given.

1.1. Overview of Congestion Hours

1.1.1. Energy – DA, HA, and RT Energy Markets

9/1/99 to 8/31/00

For the period from 9/1/99 to 8/31/00, there were 3096 hours of Path 15 DA congestion, 1392 hours of HA congestion and 1318 hours of RT congestion. Combining all of the hours resulted in an overall set of 3392 hours for which DA, HA or RT congestion occurred on Path 15.

9/1/00 to 11/25/00[1]

For the period from 9/1/00 to 11/25/00, there were 1993 hours of Path 15 DA congestion, 1689 hours of HA congestion and 1469 hours of RT congestion. Combining all of the hours resulted in an overall set of 2360 hours for which DA, HA or RT congestion occurred on Path 15.

1.1.2. Ancillary Service Markets

9/1/99 to 8/31/00

For the analysis period from 9/1/99 to 8/31/00, there were 1720 hours of Path 15 DA A/S congestion[2], and 262 hours of Path 15 HA A/S congestion. Combining all of the hours resulted in an overall set of 1761 hours for which DA and HA A/S congestion occurred on Path 15.

9/1/00 to 12/31/00

For the period from 9/1/00 to 12/31/00, there were 330 hours of Path 15 DA A/S congestion, and 58 hours of Path 15 HA A/S congestion. Combining all of the hours resulted in an overall set of 371 hours for which DA and HA A/S congestion occurred on Path 15.

1.2. Cost Summary

Using both the Low and 25% unconstrained price estimations, the following summary tables provide the total increase of costs for the three different markets, (DA, HA PX energy markets and ISO real-time market, the A/S markets, and the OOM energy) in the two time periods.

9/1/99 to 8/31/00

Type of Cost	Net Cost Using Low (Millions)	Net Cost Using 25% (Millions)
Energy (DA, HA, and RT)	-9.1	-45.24
OOM Energy	0.60	0.60

[1] We are limited to 11/25/00 instead of 12/31/00 due to meter data availability.
[2] A/S congestion is determined if there is a split in the price of any A/S product from NP15 to SP15 zones.

Ancillary Services	61	34
Total	**52.5**	**-10.64**

9/1/00 to 12/31/00

Type of Cost	Net Cost Using Low (Millions)	Net Cost Using 25% (Millions)
Energy (DA, HA, and RT)	134	-9
OOM Energy	12.5	12.5
Ancillary Services	22.7	13.4
Total	**169.2**	**16.9**

In summary, for the combined periods of 9/1/99 to 8/31/00 and 9/1/00 to 12/31/00 the cost due to Path 15 congestion is up to $**221.7** Million.

With regard to the future, without the PX as a power pool or the Congestion Management Reform proposal of the eleven Locational Pricing Areas (LPAs) the Path 15 congestion does not disappear. In fact, the Path 15 congestion costs would most likely increase further than demonstrated in this report.

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2. Overview of Congestion Management Process

2.1. Day Ahead Congestion Management

The electric market structure adopted in California assigned the ISO the role of allocating scarce transmission resources through a competitive congestion management process in the Forward Markets and in real time as operating the Balancing Market. Scheduling Coordinators were assigned the function of matching electricity supply to demand and coordinating energy transactions with arrangements for transmission services. The ISO allocates transmission based on the values the SCs place on the transmission. SCs communicate the values that they place on transmission through pairs of adjustment bids they submit to the ISO. The ISO selects the adjustment bids, maintaining the balance of each SC's scheduling portfolio. Using these pairs to adjust each SC's portfolio and maintaining the balance within each SC's portfolio is referred to as the Market Separation Rule.

Specifically, the ISO manages congestion using a zonal-based approach. Congestion occurring on interfaces (also called "paths") between congestion zones is referred to as "Inter-Zonal Congestion." Congestion occurring due to network constraints within a Congestion Zone is referred to as Intra-Zonal Congestion or AZCM. The objective of the ISO's Congestion Management process is to allocate scarce Inter-Zonal transmission capacity to the users who value use of that transmission capacity the highest. The ISO allocates transmission to each Scheduling Coordinator (SC) based on the incremental and decremental Adjustment Bids submitted by each SC. The incremental and decremental Adjustment Bids submitted by SCs for each Zonal Interface constitute implicit bids for use of such Inter-Zonal transmission capacity. The costs that arise from the ISO's Congestion Management process are allocated to customers that use the constrained paths, in most cases, according to the value that they place upon use of that path, as determined by their Adjustment Bid.

The ISO's Inter-Zonal Congestion Management software ("CONG") is formulated to minimize the net cost of re-dispatch, as determined by the SCs' submitted incremental and decremental Adjustment Bids. The objective function of the optimization is equivalent to the net power generation cost objective used in conventional OPF applications. The control variables in the Inter-Zonal Congestion Management optimization are all SCs' adjustable generators, loads, and inter-tie schedules in all Congestion Zones and Scheduling Points. The shadow costs of the constrained transmission paths produced by the optimization are used in the ISO's settlement system to calculate the charges for using these paths. The ISO assess these "usage charges" to each SC that schedules over the constrained path. Since the value of the objective function is not equal to total energy costs, the zonal prices produced by the Congestion Management process are not used to settle forward-market energy costs. The cost of Energy in the forward markets is determined by SCs.

The constraints included in the Inter-Zonal Congestion Management optimization include limits on control variables (e.g., limits on generators), the nodal active power flow balance equations and the Inter-Zonal Interface active power flow inequality constraints. Intra-Zonal constraints are ignored. These constraints are common to all OPF formulations. However, an additional set of constraints, not applicable to conventional OPFs, is added in CONG to enforce the Market Separation Rule. These constraints need to be formulated for all but one SC, the latter being referred to as the "reference Scheduling Coordinator." (The market separation and nodal power balance constraints will force the reference SC's portfolio to be balanced at the solution without explicitly formulating a constraint for it). Enforcement of the Market Separation Rule is necessary in order to ensure that the ISO does not, in the process of managing transmission Congestion, interfere with or arrange energy transactions. The ISO enforces the market separation rule by 1) requiring that each SC submit a balanced Schedule, where Generation and Imports equal Load and Exports, and 2) only utilizing Adjustment Bids in matched pairs. Thus, if the ISO increments a resource within an SC's portfolio, the ISO must at the same time decrement by an equal amount a corresponding resource within the same SC's portfolio.

Within CONG, the Market Separation Rule enables the ISO to determine the value which each SC independently and voluntarily (i.e., without the ISO arranging trades between SCs) places on use of the ISO's Inter-Zonal Interfaces. Because of the Market Separation Rule, CONG produces the same mathematical result as a set of coordinated transmission rights auctions. In these auctions, each SC bids for the use of Inter-Zonal Interfaces by specifying the SC's marginal value for use of the Interfaces, as specified in its Adjustment Bids. An SC can also offer to make transmission rights available to the marketplace by offering to create counter-flows across the Inter-Zonal Interfaces.

As noted above, the difference between an SC's incremental and decremental Adjustment Bids across an interface establish its value for use of the interface. For example, if an SC submits an incremental bid of $15 on one side of an interface and a decremental bid of $10 on the other side of the interface, the value it places on the use of the interface is $5. Importantly, the magnitude of the incremental and decremental bids does not alter the outcome of the Congestion Management process so long as the difference between the bids remains the same. For example, if SC1 submits an Adjustment Bid with an incremental bid of $15 and a decremental bid of $10 and SC2 submits an Adjustment Bid with an incremental bid of $50 and a decremental bid of $45, both SC1 and SC2 place the same value on using that interface (i.e., $5). Consequently, since it is the relative difference between a SC's incremental and decremental bids that constitute its implicit bid for transmission (i.e., its Adjustment Bid), Adjustment Bids do not have to reflect the energy cost of the corresponding resources (unless the SC uses the Adjustment Bids to calculate an energy price like the PX).

2.2. Real-Time Congestion Management

This Section describes how the ISO carries out Real-Time Inter and Intra-Zonal Congestion Management.

2.2.1. Real-Time Inter-Zonal Congestion Management

The ISO mitigates real-time inter-zonal congestion by dividing the imbalance energy market into congestion regions, and procuring imbalance energy separately in each region. Congestion regions are unions of congestion zones where the interconnecting inter-zonal interfaces are free from congestion, but the interfaces between regions are congested. In real time, congestion regions may differ for each 10-minute dispatch interval. The effect of the division of the imbalance energy market is that the 10-minute market clearing prices (MCPs) for imbalance energy may differ by congestion region. The price differential between any two congestion regions is a manifestation of real-time congestion between these regions. Real-time congestion revenues are collected by the ISO as part of its real-time settlement. These revenues are distributed evenly to metered demand as part of the revenue neutrality charge.

Currently, the ISO divides the imbalance energy market only across internal inter-zonal interfaces and not interties. The 10-minute MCPs for imbalance energy at an intertie cannot differ from the MCPs of the adjoining congestion zone, even if the inter-tie is congested. This situation does not provide accurate locational price signals for the value of imbalance energy and is inconsistent with the forward market inter-zonal congestion management protocol. Additionally, this limitation allows opportunities for gaming and does not provide incentives for proper bidding behavior.

The ISO's real-time imbalance energy procurement software could be modified to allow for the division of imbalance energy market across inter-ties. This would permit different 10-minute MCPs at the inter-ties and the adjoining congestion Zones. These MCPs would be accurate price signals, market efficiency would increase, and opportunities for gaming would be reduced.

2.2.2. Real-Time Intra-Zonal Congestion Management

Where the ISO has determined workable competition exists, real-time intra-zonal congestion is resolved by selecting bids out of sequence from either the imbalance energy stack or unused adjustment bids that were submitted in the forward markets. Where such workable competition does not exist, or if bids in workably competitive areas are insufficient to resolve congestion, the ISO may dispatch RMR units, or resort to the Out-Of-Market (OOM) protocol.

Resources participating in the competitive resolution of intra-zonal congestion are paid their incremental adjustment bid and charged their decremental adjustment bid. RMR units are paid according to the RMR contract. Resources dispatched under OOM are paid the OOM price (ex-post price under abnormal conditions and as bid under normal conditions). The net cost of real-time intra-zonal congestion management is distributed evenly to all metered demand in the corresponding zone through the Grid Operations Charge (GOC).

3. Overview of the Analysis

In this analysis we compare the aggregated zonal energy costs for PX load resources that are incurred due to congestion on Path 15 to an estimate of costs that would have been incurred if this path had sufficient capacity and were not congested. This analysis is limited to the impact on the PX zonal energy clearing price in the PX Day-Ahead Market, Hour-Ahead Market and the impact on the ISO's Imbalance Energy Market as it relates to load resources scheduled through the PX.

Also included in this analysis were a comparison with the Out-of-Market energy costs in real-time and the Ancillary Service costs in the Day-Ahead and Hour-Ahead that were incurred due to congestion on Path 15 with an estimate of costs that would have been incurred if this Path had sufficient capacity and were not congested.

This analysis covers the 12-month period of 9/1/99 to 8/31/00 for Path 15, as well as the time period from 9/1/00 to 11/25/00. The analysis cannot be completed for the entire time period of the year 2000 due to the availability of the metered data for the real-time load.

4. Background on Cost impacts of Congestion

4.1. Impact on Day-Ahead PX Energy Costs

4.1.1. Path 15 Consideration

When Path 15 becomes congested in the DA market, it has the effect of lowering the PX zonal price in one zone and increasing the price in the other. Since, in general, the congestion on Path 15 is in the South to North direction the prices in NP15 are generally higher than the prices in SP15 (and ZP26 after 2/1/00). On the other hand, if there were no congestion on Path 15, there would be just one PX DA market clearing price.

The zonal energy load costs due to congestion are calculated by multiplying the constrained zonal market clearing price and the constrained zonal market clearing load quantity (CMCQ). Likewise, the zonal energy costs without congestion is calculated by multiplying the unconstrained zonal market clearing price and the unconstrained zonal market clearing load quantity (UMCQ).

The cost impact would be the sum of the individual zonal costs under congestion as compared to the one system cost without congestion.

The PX publishes both the zonal constrained market clearing prices, which result from congestion and the unconstrained market clearing price which is calculated assuming no congestion. The zonal constrained market clearing load quantities are the final schedules that are produced by the ISO congestion management process. The zonal unconstrained market clearing load quantities are the advised preferred schedules that are used as input in the congestion management process.

4.2. Impact of DA Congestion in Real-Time

DA congestion has also an impact that manifests itself in real-time. In many cases of DA congestion on Path 15, the load in one or both zones is adjusted to help alleviate congestion in the DA. In the case of Path 15, the load in NP15 is generally decreased and thus this amount is not purchased in the DA market. Obviously, if we had no DA congestion in this case this amount would have been purchased in the DA market. This amount of load will show up in real-time and must be served by imbalance energy at the unconstrained average hourly imbalance energy price if there were no congestion. If, in fact, the path is limited in real-time, this load will be served in real-time at the constrained average hourly imbalance energy price.

4.3. Impact on the Imbalance Energy Market in Real-Time

4.3.1. Path 15 Consideration

When Path 15 is congested in the South to North direction in real-time, it is impossible to get more energy across this path from SP15 (or ZP26) to serve load and export in NP15. If there is load and export deviation that needs to be supplied in real time and the cheapest resources are in SP15 (or ZP26), the BEEP stack must be split and the energy must be supplied by more expensive resources in NP15. Thus, Path 15 has an impact on the Imbalance Energy price used in the settlement of uninstructed deviations.

If there were no congestion in real-time on Path 15, the load deviation would have been charged the product of the unconstrained price and the amount of load deviation. With the impact of the path taken into consideration, the load deviation in NP15 is now charged the product of the NP15 price and the amount of load deviation. Note that this load deviation may be different under the conditions of Path 15 and an upgraded Path 15 for which congestion does not occur.

The ISO does not explicitly calculate this unconstrained average hourly Ex-post price. In Section 6 we propose a methodology to estimate this unconstrained energy price.

5. Cost Comparison Methodology

The cost comparison methodology is described in this section conceptually. The detailed formulas are provided in Appendix A.

The objective is to calculate the incremental cost to demand as a result of inter-zonal congestion. For example, we would like to know how much savings to NP15 load can be realized if Path 15 is not enforced, thus eliminating northbound congestion. In order to identify such savings, we compare the total energy costs to load with congestion and without congestion. Specifically, the cost of congestion to demand, i.e., the savings that can be realized by transmission upgrade, is calculated as follows:

$$\text{Cost of Congestion} = (C_{DA} + C_{HA} + C_{RT}) - (C^{0}_{DA} + C^{0}_{HA} + C^{0}_{RT}) \qquad (1)$$

The symbols in the equation are defined as follows:

C_{RT} = Real-time zonal energy cost

C_{HA} = HA zonal energy cost

C_{DA} = DA zonal energy cost

C^0_{RT} = Real-time zonal energy cost without congestion after transmission upgrades

C^0_{HA} = HA zonal energy cost without congestion after transmission upgrades

C^0_{DA} = DA zonal energy cost without congestion after transmission upgrades

The equation in (1) can be rewritten as follows:

$$\text{Cost of Congestion} = (C_{DA} - C^0_{DA}) + (C_{HA} - C^0_{HA}) + (C_{RT} - C^0_{RT}) \qquad (2)$$

The three terms in (2) are explained as follows:

$(C_{DA} - C^0_{DA})$ = The cost of congestion to zonal demand in DA market
$(C_{HA} - C^0_{HA})$ = The cost of congestion to zonal demand in HA market
$(C_{RT} - C^0_{RT})$ = The cost of congestion to zonal demand in RT market

Let us illustrate the calculation of the costs of congestion by an example.

Calculation of $(C_{DA} - C^0_{DA})$

Suppose the PX DA unconstrained market clearing quantity and price for a given hour and a given zone are 15,000 MW and $40/MWh respectively. The corresponding PX DA final schedule and price are 12,000 MW and $45/MWh respectively. The cost of congestion in DA is: $600,000 - $540,000 = $60,000.

Calculation of $(C_{HA} - C^0_{HA})$

Suppose the PX HA unconstrained market clearing quantity and price for a given hour and a given zone are 1,500 MW and $40/MWh respectively. The corresponding PX HA constrained quantity and price is 1,000 MW and $45/MWh respectively. The cost of congestion in HA is: $60,000 - $45,000 = $15,000.

Calculation of $(C_{RT} - C^0_{RT})$

Let the actual consumption in this zone be 17,000 MW. The imbalance energy in the zone is 17,000 MW – 12,000 MW (DA) – 1,000 MW (HA) = 4,000 MW. Suppose the real-time zonal price is $80/MWh; the cost of imbalance energy is 4,000 MW * $80/MWh = $320,000. If the transmission line were upgraded, there would be no congestion in DA and HA markets; the imbalance energy in the zone would be 17,000 MW – 15,000 MW (DA) – 1,500 MW (HA) = 500 MW. The unconstrained real-time price needs to be estimated using available data. The method for estimating this price is discussed in the next section. Let us assume for now that the unconstrained real-time price would be $70/MWh if the transmission line were upgraded; the cost of imbalance energy would be 500 MW * $70/MWh = $35,000. Therefore, the cost of congestion in real-time is $320,000 - $35,000 = $285,000.

Total Cost of Congestion

The total cost of congestion for the given hour for the given zone is as follows:

$$\begin{aligned}\text{Cost of Congestion} &= (C_{DA} - C^0_{DA}) + (C_{HA} - C^0_{HA}) + (C_{RT} - C^0_{RT}) \\ &= \$60{,}000 + \$15{,}000 + \$285{,}000 \\ &= \$360{,}000\end{aligned}$$

6. Estimating Unconstrained Prices

6.1. Energy – Unconstrained Real-Time Price

As seen in the example, in order to calculate the cost of real-time congestion, the unconstrained real-time price is needed. However, the ISO does not explicitly calculate this value under conditions of real-time congestion and thus must estimate this value.

There may be many ways to estimate the unconstrained real-time price. The most accurate way is to re-run the BEEP application without consideration of real-time limits on Path 15. Since re-running the BEEP is extremely time consuming (due to data and software requirements), an estimate of this unconstrained real-time price needs to be created. There are two general methodologies presented here that can perform this estimation. The first is to use the two constrained prices one in SP15 and one in NP15 for a given hour to estimate the unconstrained price. The second is to use unconstrained prices from hours where there is no real-time congestion.

For the first method we can use the two constrained prices in various ways to estimate the unconstrained price. Two of these are listed below in the bullets:

- **25% from the lower real-time zonal price**: For example, if NP15 price is $50/MWh and SP15 price is $40/MWh, the unconstrained price would be the 40 + 0.25 * (50-40) = $42.5/MWh.

- **The lower of the two real-time zonal prices:** For example, if NP15 price is $50/MWh and SP15 price is $40/MWh, the unconstrained price would be $40/MWh.

The second method of estimating the unconstrained price would be the following:

- Use average prices for unconstrained hours as proxies for when there is real-time congestion. The methodology used in this analysis for estimating the unconstrained real-time price (URTP) is to average the unconstrained real-time prices for similar hours over each month taking into account weekend and weekday hours. These hours are where the zonal prices for NP15, SP15 and ZP26 (over the period applicable) are all equal.

For example, for Hour-ending (HE) 11 for the month of August, 2000, for a weekday, there are 23 of these HE 11's in the month. Out of these 23 hours, there are 19 for which the data shows the zonal prices for NP15, SP15 and ZP26 are all equal, thus giving one real-time price for the ISO control area. These 19 real-time prices are then averaged to estimate an URTP that would be used for the other 4 weekday HE 11's in August.

The two alternatives of the **first method**, 25% from the lower real-time zonal price (referred to throughout this report as *25%*) and the lower of the two real-time zonal prices (referred to throughout this report as *Low*), are used in this report to estimate the unconstrained real-time price. Costs are calculated using both of these methods and we assume that the true unconstrained costs would fall somewhere within the range of these two costs. The main assumption that we are utilizing is that with more capacity on Path 15, there would be more dispatch in SP15 and with this dispatch the price would go above the SP15 constrained price, but not larger than 25% above this constrained price. Thus, we assume that the resulting costs would lie in the range given by the Low estimation and the 25% estimation.

6.2. Out-of-Market

The Out-of-Market costs will be derived for the following conditions:

- Specific OOM calls for Path 15 congestion
- OOM calls for NW1, NW2, and SR2 with and without BEEP split for Path 15
- Additional OOM calls for system resources with BEEP split for Path 15

For the unconstrained Path 15 OOM price, the price for the day and hour in which the OOM call was made will be derived from the SP15 incremental price.

6.3. Ancillary Services – Unconstrained DA, HA Price

As seen in the example, in order to calculate the additional cost of Ancillary Services (RegUp, RegDn, Spin, NonSpin and Replacement Reserve) due to the congestion, the unconstrained Ancillary Service price is needed. However, the ISO does not explicitly calculate this value unless the Ancillary Service Auction is run and the procurement is analyzed. If the A/S procurement does not satisfy sufficient distribution across the control area with the Path 15 constraints, then the A/S auction is re-run with Path 15 split.

Again, the same two methods and resulting variations can be used as ways to estimate the unconstrained prices. For this analysis, the two alternatives of the **first method** are used in this report.

7. Cost Impact Results

In this section we compare the aggregate zonal DA, HA, and real-time energy costs for NP15 and SP15 PX load under conditions of congestion and no congestion on Path 15 (South to North). In addition, OOM energy costs and A/S procurement costs for NP15 and SP15 are compared for conditions of congestion and no congestion on Path 15.

7.1. Path 15 Analysis – DA, HA, and Real-time Energy

The following tables provide the congestion related DA, HA and real-time energy costs associated with Path 15. An overall analysis is provided at the end of this section, and provides the reasons underlying the energy costs that are calculated.

For the period of 9/1/99 through 8/31/00, Table 1 provides the number of hours where congestion was present on Path 15 in the south to north direction in the energy markets.

Table 1, Congestion Hours for Path 15 for the Energy Markets from 9/1/99 through 8/31/00

Market	Number of Congestion Hours
DA	3096
HA	1392
Real-time (NP15 price was higher than the SP15 price)	1318
Combined Hours **(Union of DA, HA and RT)**	3392

For the period of 9/1/00 through 11/25/00, Table 2 provides the number of hours where congestion was present on Path 15 in the south to north direction in the energy markets.

Table 2, Congestion Hours for Path 15 for the Energy Markets from 9/1/00 through 11/25/00

Market	Number of Congestion Hours
DA	1993
HA	1689

Real-time (NP15 price was higher than the SP15 price)	1469
Combined Hours (Union of DA, HA and RT)	2360

7.1.1. Energy Cost of Path 15 Northbound Congestion to NP15 Load

In this section we provide data associated with the energy cost of congestion analysis for NP15 when Path 15 is congested.

Table 3 **Congested** and **UnCongested** Cost in Millions of NP15 PX Load for Path 15 congestion analysis for energy from 9/1/99 to 8/31/00

NP15 Load (Energy)	**DA Costs (Millions)**	**HA Costs (Millions)**		**RT-25% (Millions)**	**RT-Low (Millions)**
Congested	1,202	1.3		518	
UnCongested	1,189	5		250	214
Congested-UnCongested	**13**	**-3.7**		**268**	**304**
Totals: Congested - UnCongested					
Using 25% (Millions)	13 – 3.7 + 268 = **277.3**				
Using Low (Millions)	13 – 3.7 + 304 = **313.3**				

Table 4 **Congested** and **UnCongested** Cost in Millions of NP15 PX Load for Path 15 congestion analysis for energy from 9/1/00 to 11/25/00

NP15 Load (Energy)	**DA Costs (Millions)**	**HA Costs (Millions)**		**RT-25% (Millions)**	**RT-Low (Millions)**
Congested	848	0.44		1069	
UnCongested	1024	0.788		531	421

Congested-UnCongested	**-177**	**0.343**		**538**	**648**

Totals: Congested - UnCongested	
Using 25% (Millions)	-177 + 0.343 + 538 = **361**
Using Low (Millions)	-177 + 0.343 + 648 = **471**

Table 5 **Congested** and **UnCongested** MWhs (in 1000 MWhs) of NP15 PX Load for Path 15 congestion analysis for energy for 9/1/99 to 8/31/00

NP15 Load	DA (1000 MWh)	HA (1000 MWh)	RT (1000 MWh)	Total (1000 MWh)
Congested	21,757	7	4,613	26,377
UnCongested	24,000	53	2,324	26,377
Congested-UnCongested	**-2243**	**-46**	**2289**	**0**

Table 6 **Congested** and **UnCongested** MWhs (in 1000 MWhs) of NP15 PX Load for Path 15 congestion analysis for energy for 9/1/00 to 12/31/00

NP15 Load	DA (1000 MWh)	HA (1000 MWh)	RT (1000 MWh)	Total (1000 MWh)
Congested	7,136	3	6005	13,144
UnCongested	8596	6	4542	13,144
Congested-UnCongested	**-1,460**	**-3**	**-1,463**	**0**

7.1.2. Energy Cost of Path 15 Northbound Congestion to SP15 Load

Tables 7 and 8 provide the energy cost and associated data for SP15 load for the Path 15 congestion analysis.

Table 7 **Congested** and **UnCongested** Cost (in Millions) of SP15 PX Load for Path 15 congestion analysis for energy for 9/1/99 to 8/31/00

SP15 Load (Energy)	**DA (Millions)**	**HA (Millions)**		**RT-25% (Millions)**	**RT-Low (Millions)**
Congested	1,494	9.3		22.5	
UnCongested	1,800	9.6		38.74	38.6
Congested-UnCongested	**-306**	**-0.3**		**-16.24**	**-16.1**
Totals: Congested - UnCongested					
Using 25% (Millions)	-306 – 0.3 – 16.24 = **-322.54**				
Using Low (Millions)	-306 – 0.3 – 16.10 = **-322.4**				

Table 8 **Congested** and **UnCongested** Cost (in Millions) of SP15 PX Load for Path 15 congestion analysis for energy for 9/1/00 to 12/31/00

SP15 Load (Energy)	**DA (Millions)**	**HA (Millions)**		**RT-25% (Millions)**	**RT-Low (Millions)**
Congested	1,618	12		-8	
UnCongested	1,959	9		24	-9
Congested-UnCongested	**-341**	**3**		**-32**	**1**
Totals: Congested - UnCongested					
Using 25% (Millions)	-341 + 3 -32 = **-370**				
Using Low (Millions)	-341 + 3 -1 = **-339**				

Table 9 **Congested** and **UnCongested** MWhs (in 1000 MWhs) of SP15 PX Load for Path 15 congestion analysis for energy for 9/1/99 to 8/31/00

SP15 Load	DA (1000 MWh)	HA (1000 MWh)	RT (1000 MWh)	Total (1000 MWh)
Congested	34,457	75	-907	33,625
UnCongested	34,079	84	-538	33,625
Congested-UnCongested	**378**	**-9**	**369**	**0**

Table 10 **Congested** and **UnCongested** MWhs (in 1000 MWhs) of SP15 PX Load for Path 15 congestion analysis for energy for 9/1/00 to 11/25/00

SP15 Load	DA (1000 MWh)	HA (1000 MWh)	RT (1000 MWh)	Total (1000 MWh)
Congested	16,657	115	-384	16,388
UnCongested	16,297	72	19	16,388
Congested-UnCongested	**360**	**43**	**-403**	**0**

Note that the real-time MWhs for SP15 in the congested case are negative indicating an overall over-scheduling of energy. Also notice that the different unconstrained real-time prices have little effect on the unconstrained price for SP15.

Table 11 Net costs in Millions to load for Path 15 congestion analysis for energy for 9/1/99 to 8/31/00

Path 15 (Energy)	Congested Costs - UnCongested Costs				
	DA (Millions)	**HA (Millions)**	**Real-Time (Millions)**		
				RT-25%	**RT-Low**

NP15	13	-3.7		268	304
SP15	-306	-0.3		-16.24	-16.1
Net Cost to NP15 and SP15 Load	**-293**	**-4**		**251.76**	**287.9**
Totals: Net Costs to NP15 and SP15 Load					
Using 25% (Millions)	-293 - 4 + 251.76 = **-45.24**				
Using Low (Millions)	-293 - 4 + 287.9 = **-9.1**				

Table 12, Net costs in Millions to load for Path 15 congestion analysis for energy for 9/1/00 to 11/25/00

Path 15 (Energy)	**Congested Costs - UnCongested Costs**				
	DA (Millions)	**HA (Millions)**	**Real-Time (Millions)**		
				RT-25%	**RT-Low**
NP15	-177	0.343		538	648
SP15	-341	3		-32	1
Net Cost to NP15 and SP15 Load	**-518**	**3**		**506**	**649**
Totals: Net Costs to NP15 and SP15 Load					
Using 25% (Millions)	-518 + 3 + 506 = **- 9**				
Using Low (Millions)	-518 + 3 + 649 = **134**				

7.1.3. Analysis of Results for Path 15

In this section we provide a qualitative analysis for the energy costs results. This analysis is confined to the period of 9/1/99 to 8/31/00 since the second period of 9/1/00 to 11/25/00 follows generally except for the large cost increase in NP15 in the real-time which is noted at the end of this section.

For the period of 9/1/99 to 8/31/00, what we see for Path 15 is that there is a negative net cost to load due to congestion on this path for both of the unconstrained price estimations. Furthermore, for each of the two costs, we see that this negative net cost comes about because the negative cost to SP15 load outweighs the increase in costs to NP15 load. If we look at the different markets we see that this negative net cost for SP15 load came for the most part in the DA market. While for NP15, the majority of cost increase came in the real-time market.

During DA congestion on Path 15 in the northbound direction, the load in NP15 and in SP15 take part in the Congestion Management process. In general, load in NP15 will decrease to help alleviate congestion (as well as export decreasing and/or generation and import increasing). In SP15, load also participates by increasing (as well as export increasing and/or generation and import decreasing).

What we see is that the resulting zonal price change as compared to the unconstrained MCP (UMCP) in SP15 is greater than the NP15 zonal price changes. This results in a much lower SP15 price from the UMCP. Comparatively, there is little change or increase in the NP15 zonal prices from the UMCP.

Upon analysis, there are 2989 hours (in the period of 9/1/99 to 8/31/00) out of our Path 15 study set where the DA NP15 constrained MCP (CMCP) is greater than the DA SP15 CMCP. Out of this set, there are 2331 (2331/2989 = 80%) hours where the change in the SP15 price is greater than the change in the NP15 price. That is:

$$\frac{UMCP - SP15}{UMCP} > \frac{NP15 - UMCP}{UMCP}.$$

Through their participation in congestion management, the overall effect on NP15 load is to decrease the MWh and increase the price slightly, with the overall result being a slight increase in the NP15 DA zonal energy cost to the load.

The overall effect on SP15 load is to increase the load while decreasing the price substantially, resulting in an overall negative net cost to SP15 load.

SP15 Load in Real-Time:

Since the load in SP15 is increased through the congestion management process there are times when there is a negative real-time imbalance, i.e.; scheduled demand is larger than the metered demand.

Note that in Table 8, the under scheduled MWhs for both the congested and uncongested situations are lower than the over-scheduled MWh amounts, but that the costs are the reverse; the costs for the under-scheduling are more than the negative cost for the over-scheduling. We try to explain these observations as follows.

Over-scheduled situation:

First of all, we must remember that the NP15 load almost always decreases during the DA congestion management process. Thus there is a deficiency of generation to serve the actual NP15 load that will show up in real-time. And that about only 1/3 of the time that we are studying for Path 15 congestion is there actually real-time congestion in the south to north direction on Path 15.

For the overscheduled situation, SP15 generation is larger than SP15 actual load. Since we must have balanced schedules in the forward markets, the generation must equal load and since scheduled load is larger than actual (metered) load, so must the generation (assuming these controllable resources generate at their scheduled levels). This excess generation in SP15 will be able to serve the excess load in NP15 (due to NP15 under-scheduling). Thus, this reduces the need to procure generation in real-time and thus will keep real-time prices lower than if this excess SP15 generation was not scheduled. Plus, for the 2/3 of the time when there is no real-time congestion on Path 15, all of this excess generation can be used to serve the NP15 load, thus keeping real-time prices from further rising. This results in lower real-time prices for SP15, which leads to the lower average prices (see Appendix B).

Under-scheduled situation:

For the under-scheduled situation, generation needs to be procured to serve both the SP15 and NP15 load. In doing this procurement, the price will be driven up.

NP15 Load Increased Costs in RT:

For NP15 load, the majority of the costs between the congested and uncongested comes in the real-time market as shown in Table 3. However, this amount is not always enough to overcome the negative cost to SP15 load in the DA market. The main reason for this is that (as was noted earlier), only 1/3 of the time there is real-time congestion on Path 15, and thus 2/3 of the time there is just one (BEEP not split) real-time price. Thus, 2/3 of the time the prices are lower than they would be when real-time congestion occurred. In fact, out of the $518 million for real-time congestion, $383 million or 74% were incurred during the 1318 hours of real-time congestion.

For the time period of 9/1/00 to 11/25/00 there was a large increase in the costs of NP15 in the real-time market (over the Low to 25% range). This is due to the fact that the real-time prices were very high during this period.

7.2. Path 15 Analysis – Out-of-Market

The following table provides the Out-of-Market MWhs and costs associated with Path 15 constraints. Due to the data available, the OOM calls are broken down into a number of different categories.

Table 13, OOM calls for energy from 9/1/99 through 8/31/00

OOM Call	MWhs	Cost (Millions)	RT SP15 Inc Cost (Millions)	Net Cost (Millions)
Branch Group – NW1, NW2, and SR2	***60,663***	***30.3***	***27.62***	***2.694***
Branch Group – NW1, NW2, and SR2 with BEEP Split	1,475	0.643	0.038	0.605
Total		0.643	0.038	0.605

*Not included in Totals

Table 14, OOM calls for energy from 9/1/00 through 12/31/00

OOM Call	MWhs	Cost (Millions)	RT SP15 Inc Cost (Millions)	Net Cost (Millions)
Path 15 Designation	38.5	9.05	6.29	2.759
Branch Group – NW1, NW2, and SR2	***43.3***	***10.5***	***8.437***	***2.09***
Branch Group – NW1, NW2, and SR2 with BEEP Split	16.4	3.95	1.94	2.01
Insufficient Resources with BEEP Split	87.9	22.0	14.256	7.749
Total		35.01	22.49	12.52

*Not included in Totals

The real-time costs for SP15 Incremental use the assumption that all of the energy could have been procured from SP15.

7.3. Path 15 Analysis – Ancillary Services

This section provides the cost analysis of the impact of Path 15 congestion on the Ancillary Services Market (RegUp, RegDn, Spin, NonSpin and Replacement Reserve). A brief explanation of this analysis follows.

The hours are first determined for which the prices for NP15 is not equal to the SP15 or (ZP26 after 1/31/00) for any of the five A/S products in either the DA or HA markets. For these hours the total procurement (MW) for the area south of Path 15 and North of Path 15 in the DA for each of the A/S products is multiplied by the corresponding product price in that area (either NP15 or SP15/ZP26). Thus a North of Path 15 constrained cost is determined for each product as well as a south of Path 15 constrained cost for each product. The same is performed for the HA market but only to the incremental amount, i.e., final HA procurement minus the final DA procurement.

For the unconstrained situation, the above methodology is applied with the unconstrained price estimation that is described in Section 6.

The following tables provide the congestion related DA and HA Ancillary Service costs associated with Path 15.

For the period of 9/1/99 through 8/31/00, Table 15 provides the number of hours where A/S congestion was present on Path 15.

Table 15, A/S Congestion Hours for Path 15 for 9/1/99 through 8/31/00

Market	Number of Congestion Hours
DA	1720
HA	262
Combined Hours **(Union of DA and HA)**	1761

Table 16, A/S Congestion Hours for Path 15 for 9/1/00 through 12/31/00

Market	Number of Congestion Hours
DA	330
HA	58
Combined Hours	371

(Union of DA and HA)	

7.3.1. Cost of Path 15 Northbound A/S Congestion for NP15 Capacity Procurement

In this section we provide data associated with the cost of A/S congestion analysis for capacity procured in NP15.

Table 17, **Congested** and **UnCongested** A/S Cost in Millions for NP15 due to Path 15 congestion, from 9/1/99 to 8/31/00

NP15	DA Costs (Millions)	HA Costs (Millions)	DA +HA Costs (Millions)
Congested	77	26	103
UnCongested (Low)	59	23	82
UnCongested (25%)	68	24	92
Congested-UnCongested (Low)	**18**	**3**	**21**
Congested-UnCongested (25%)	**9**	**2**	**11**

Table 18, Procured MWs (in 1000 MWs) for NP15 from 9/1/99 to 8/31/00

NP15	DA (1000 MW)	HA (1000 MW)	Total (1000 MW)
	2,014	496	2,510

Table 19, **Congested** and **UnCongested** A/S Cost in Millions for NP15 due to Path 15 congestion, from 9/1/00 to 12/31/00

NP15	DA Costs (Millions)	HA Costs (Millions)	DA + HA Costs (Millions)

Congested	29	13	42
UnCongested (Low)	23	12	35
UnCongested (25%)	26	12.2	38.2
Congested-UnCongested (Low)	**6**	**1**	**7**
Congested-UnCongested (25%)	**3**	**0.8**	**3.8**

Table 20, Procured MWs (in 1000 MWs) for NP15 from 9/1/00 to 12/31/00

NP15	DA (1000 MW)	HA (1000 MW)	Total (1000 MW)
	383	143	526

7.3.2. Cost of Path 15 Northbound A/S Congestion for SP15 Capacity Procurement

Table 21, **Congested** and **UnCongested** A/S Cost in Millions for SP15 due to Path 15 congestion, from 9/1/99 to 8/31/00

SP15	DA Costs (Millions)	HA Costs (Millions)	DA + HA Costs (Millions)
Congested	133	21	154
UnCongested (Low)	95	19	114
UnCongested (25%)	111	20	131
Congested-UnCongested (Low)	**38**	**2**	**40**
Congested-UnCongested (25%)	**22**	**1**	**23**

Table 22, Procured MWs (in 1000 MWs) for SP15 from 9/1/99 to 8/31/00

SP15	**DA (1000 MW)**	**HA (1000 MW)**	**Total (1000 MW)**
	2,845	409	3,254

Table 23, **Congested** and **UnCongested** A/S Cost in Millions for SP15 due to Path 15 congestion, from 9/1/00 to 12/31/00

SP15	**DA Costs (Millions)**	**HA Costs (Millions)**	**DA + HA Costs (Millions)**
Congested	55	15	70
UnCongested (Low)	39	15.3	54.3
UnCongested (25%)	45	15.4	60.4
Congested-UnCongested (Low)	**16**	**-0.3**	**15.7**
Congested-UnCongested (25%)	**10**	**-0.4**	**9.6**

Table 24, Procured MWs (in 1000 MWs) for SP15 from 9/1/00 to 12/31/00

SP15	**DA (1000 MW)**	**HA (1000 MW)**	**Total (1000 MW)**
	576	144	720

The next two tables provide the overall results of the impact of Path 15 on the cost of A/S for the two time periods used throughout this report. The low unconstrained price estimate is used in these tables.

Table 25 Net costs in Millions for Path 15 A/S congestion analysis from 9/1/99 to 8/31/00

Path 15	Congested Costs - UnCongested Costs	
	Low **DA + HA** **(Millions)**	**25%** **DA + HA** **(Millions)**
NP15	21	11
SP15	40	23
Net Cost to NP15 and SP15	**61**	**34**

Thus, an additional cost in the range of $34 to $61 million is incurred for A/S procurement due to Path 15 congestion for the period of from 9/1/99 to 8/31/00.

Table 26 Net costs in Millions for Path 15 A/S congestion analysis from 9/1/00 to 12/31/00

Path 15	Congested Costs - UnCongested Costs	
	Low **DA + HA** **(Millions)**	**25%** **DA + HA** **(Millions)**
NP15	7	3.8
SP15	15.7	9.6
Net Cost to NP15 and SP15	**22.7**	**13.4**

Thus an additional cost in the range of 13.4 to $22.7 million is incurred for A/S procurement due to Path 15 congestion for the period of from 9/1/00 to 12/31/00.

7.4. Path 15 Analysis – Total Costs

The total costs are then derived from the energy costs, OOM costs, and A/S costs for the Path 15 constraint from the periods of 9/1/99 to 8/31/00 and 9/1/00 to 12/31/00.

Table 27, Net costs in Millions to load for Path 15 total congestion from 9/1/99 to 8/31/00

Type of Cost	Net Cost Using Low (Millions)	Net Cost Using 25% (Millions)

Energy (DA, HA, and RT)	-9.1	-45.24
OOM Energy	0.60	0.60
Ancillary Services	61	34
Total	**52.5**	**-10.64**

Table 28, Net costs in Millions to load for Path 15 total congestion from 9/1/00 to 12/31/00

Type of Cost	Net Cost Using Low (Millions)	Net Cost Using 25% (Millions)
Energy (DA, HA, and RT)	134	-9
OOM Energy	12.5	12.5
Ancillary Services	22.7	13.4
Total	**169.2**	**16.9**

8. Other Factors Considered in this Analysis

8.1. DA Congestion relief on Path 15 due to adjustment of Load

In a recent internal study, the behavior of the load adjustment bids was studied in the DA congestion management process for the relief of congestion on Path 15. The period of study was from July 6 to July 31, 2000 and separated into two sets of hours:

- Path 15 South to North Congestion (125 Hours)

The behavior of the DA market under these congestion conditions is summarized as follows:

- In general, PG&E and SCE and SDG&E's demand zone loads were the primary resources that were adjusted to mitigate the DA congestion.
- For Path 15 South to North congestion, **loads in NP15** were curtailed and the **generations in NP15** (or ties connected to NP15) were increased to mitigate congestion.

Thus, for Path 15 congestion, the load was mainly curtailed to resolve congestion. This curtailment of load contributes to the current problem facing the ISO of load under-scheduling. When the congestion management was simulated with this load unable to participate (no adjustment bids), the following occurred:

For Path 15 in the South to North direction, all the 125 hours converged with the usage charge rising from the 125 hourly average of $15/MW to $58/MW without the load adjustment bids.

8.2. Future Impact of Path15 Congestion on Energy Costs

In its December 15, 2000 Order[3], FERC set forth an order prescribing that market participants must schedule at least ninety-five percent of their loads prior to the real-time period, otherwise they would be subject to a penalty for their deviations from the corresponding 5 percent. This new rule may have an impact on the energy costs when congestion is present in the forward markets. Under this rule and if the market participants were to follow it, the amount of MWhs within the adjustment bids of loads that could be exercised would be limited.

In Section 7.1.3 we discussed the use of the adjustments by the demand zone loads in NP15 and SP15 to alleviate congestion and to control the resulting prices. However, if these load adjustments are now limited in terms of the MWhs they can move, other resources may now be the marginal resources in these zones that set the price.

In NP15, the load would not be able to be decremented as in the past and in general another more expensive resource would also need to be decremented (if a load) or incremented (if a generator) setting the zonal price higher. Thus, a larger increase in costs would result for the NP15 load. However, with the inability to decrement, the resulting real-time load deviation may be lower resulting in a lower real-time cost.

In SP15, the load would not be able to be incremented as much, but a lower price may result since another cheaper resource may be marginal.

Overall, it is difficult to estimate the impact of congestion on the energy costs to load under this new rule.

9. Conclusions

In this report we provided the results on the cost impact of congestion on Path 15 on:

- The energy costs for PX load resources in the DA, HA and real-time energy markets;
- The costs of calling OOM energy; and
- The costs of procuring capacity (A/S) in north and south of Path15.

[3] FEFC 93 - 61294, Order Directing Remedies for California Wholesale Electric Markets, December 15, 2000.

In summary, for the combined periods of 9/1/99 to 8/31/00 and 9/1/00 to 12/31/00 the range of increased cost due to Path15 congestion is from $**6.26** million to $**221.7** million.

10. Appendix A: Formulas for Calculating the Cost of Congestion

10.1. Definition of Symbols

The following symbols are defined for zonal prices and zonal quantities for any given zone.

C_{RT} $= P_{RT} * \Delta Q_{RT}$ (A1)

= Real-time zonal energy cost

P_{RT} = Real-time zonal energy price

ΔQ_{RT} $= Q_{RT} - Q_{HA}$

= Zonal imbalance energy

Q_{RT} = Real-time metered zonal demand

Q_{HA} = HA zonal demand final schedule

C_{HA} $= P_{HA} * \Delta Q_{HA}$ (A2)

= HA zonal energy cost

P_{HA} = HA zonal energy price

ΔQ_{HA} $= Q_{HA} - Q_{DA}$

= HA zonal incremental demand

Q_{DA} = DA demand schedule

C_{DA} $= P_{DA} * Q_{DA}$ (A3)

= DA zonal energy cost

P_{DA} = DA zonal energy price

C^0_{RT} $= P^0_{RT} * \Delta Q^0_{RT}$ (A4)

= Real-time zonal energy cost without congestion after transmission upgrades.

P^0_{RT} = Real-time zonal energy price without congestion after transmission upgrades

ΔQ^0_{RT} $= Q_{RT} - Q^0_{HA}$

= Zonal imbalance energy without congestion after transmission upgrades

Q^0_{HA} = HA zonal demand final schedule without congestion after transmission upgrades

C^0_{HA} = $P^0_{HA} * \Delta Q^0_{HA}$ (A5)

= HA zonal energy cost without congestion after transmission upgrades

P^0_{HA} = HA zonal energy price without congestion after transmission upgrades

ΔQ^0_{HA} = $Q^0_{HA} - Q^0_{DA}$

= HA zonal incremental demand without congestion after transmission upgrades

Q^0_{DA} = DA demand schedule without congestion after transmission upgrades

C^0_{DA} = $P^0_{DA} * Q^0_{DA}$ (A6)

= DA zonal energy cost without congestion after transmission upgrades

P^0_{DA} = DA zonal energy price without congestion after transmission upgrades

P_{RT_N15} = Real-time NP15 energy price

Q_{RT_N15} = Real-time NP15 metered demand

P_{HA_N15} = HA NP15 energy price

Q_{HA_N15} = HA NP15 demand final schedule

P_{DA_N15} = DA NP15 energy price

Q_{DA_N15} = DA NP15 demand schedule

ΔP_{RT_N15} = $P_{RT\_N15} - P^0_{RT\_N15}$

= The difference between the real-time ex-post prices with and without congestion

$P^0_{RT\_N15}$ = Real-time NP15 energy price without congestion after Path 15 upgrade

$Q^0_{RT\_N15}$ = Real-time NP15 metered demand without congestion after Path 15 upgrade

$P^0_{HA\_N15}$ = HA NP15 energy price without congestion after Path 15 upgrade

$Q^0_{HA\_N15}$ = HA NP15 demand final schedule without congestion after Path 15 upgrade

$P^0_{DA\_N15}$ = DA NP15 energy price without congestion after Path 15 upgrade

$Q^0_{DA\_N15}$ = DA NP15 demand schedule without congestion after Path 15 upgrade

P_{RT_S15} = Real-time SP15 energy price

Q_{RT_S15} = Real-time SP15 metered demand

P_{HA_S15} = HA SP15 energy price

Q_{HA_S15} = HA SP15 demand final schedule

P_{DA_S15} = DA SP15 energy price

Q_{DA_S15} = DA SP15 demand schedule

ΔP_{RT_S15} = $P_{RT\_S15} - P^0_{RT\_S15}$

= The difference between the real-time ex-post prices with and without congestion

$P^0_{RT\_S15}$ = Real-time SP15 energy price without congestion after Path 15 upgrade

$Q^0_{RT\_S15}$ = Real-time SP15 metered demand without congestion after Path 15 upgrade

$P^0_{HA\_S15}$ = HA SP15 energy price without congestion after Path 15 upgrade

$Q^0_{HA\_S15}$ = HA SP15 demand final schedule without congestion after Path 15 upgrade

$P^0_{DA\_S15}$ = DA SP15 energy price without congestion after Path 15 upgrade

$Q^0_{DA\_S15}$ = DA SP15 demand schedule without congestion after Path 15 upgrade

10.2. Formulas for Calculating Congestion Cost to Demand of Any Zone

The formulas are used to calculate the cost of congestion on a given path to the demand of a given zone. For example, the formulas can be applied to calculate Path 15 northbound congestion cost to NP15 demand. The formulas can also be applied to calculate Path 15 northbound congestion cost to SP15 demand.

For any given hour when there is congestion (DA, HA or real-time) on a given path, the total cost of congestion to the demand in a given zone is calculated as follows:

The Congestion Cost

$$= (C_{RT} + C_{HA} + C_{DA}) - (C^0_{RT} + C^0_{HA} + C^0_{DA})$$

$$= (C_{RT} - C^0_{RT}) + (C_{HA} - C^0_{HA}) + (C_{DA} - C^0_{DA}) \qquad \text{(A7)}$$

We discuss the evaluation of the three terms of (A7) in reverse order, starting with the DA congestion cost. Substituting (A3) and (A6) into the third term of (A7), we get:

DA Congestion Cost

$$= C_{DA} - C^0_{DA}$$

$$= \quad P_{DA} * Q_{DA} - P^0_{DA} * Q^0_{DA} \tag{A8}$$

All the four quantities used in calculating the DA market congestion cost are known; the equation of (A8) can be easily evaluated.

In order to evaluate the HA market congestion cost, substitute (A2) and (A5) into the second term of (A7).

HA Congestion Cost

$$= \quad C_{HA} - C^0_{HA}$$

$$= \quad P_{HA} * \Delta Q_{HA} - P^0_{HA} * \Delta Q^0_{HA} \tag{A9}$$

The first term in (A9) can be calculated easily because both P_{HA} and ΔQ_{HA} are known. To evaluate the second term, the PX unconstrained HA price and quantity can be used for P^0_{HA} and ΔQ^0_{HA}. However, by doing so, we implicitly make the assumption that the HA bids (quantities and prices) of the HA market are independent of the DA congestion status of the path. In other words, we assume that the same P^0_{HA} and ΔQ^0_{HA} will come out of the HA unconstrained auction regardless whether there is DA congestion.

We now turn our attention to the evaluation of the real-time (RT) congestion cost. By substituting (A1) and (A4) into the first term of (A7), we get:

Real-time Congestion Cost

$$= \quad C_{RT} - C^0_{RT}$$

$$= \quad P_{RT} * \Delta Q_{RT} - P^0_{RT} * \Delta Q^0_{RT} \tag{A10}$$

$$= \quad P_{RT} * (Q_{RT} - Q_{HA}) - P^0_{RT} * (Q_{RT} - Q^0_{HA})$$

In equation (A10), the real-time constrained zonal price P_{RT} is known. The real-time unconstrained zonal price P^0_{RT} is not known. In order to evaluate (A10), we need to estimate P^0_{RT}. There are three approaches:

- Simulate the real-time market without splitting he BEEP stack. This essentially requires re-run the real-time market for several thousand hours. This approach provides an accurate unconstrained real-time price. But this approach takes too much time to complete (both from data and software perspective).

- Estimate the unconstrained real-time ex-post price using available data. For example, using the ex-post price of similar hours when there was no real-time congestion. This method is relatively easy to apply. However, it is difficult to assess the accuracy of such estimate.

- Explore the mathematical properties to identify the lower and upper bounds of the expression in (A10). This approach avoids estimating the real-time unconstrained price. The lower bound alone may be high enough to justify the enhancement of the path. However, such bounds can only be obtained in special cases. The next two sections explore these special cases.

11. Appendix B: Additional Tables for NP15 and SP 15 results

11.1. Average Prices for NP15 Load

These Tables only apply to the period of 9/1/99 to 8/31/00.

Table B1, Average Prices for NP15 Load for Path 15 congestion analysis

NP15 Load	DA ($/MWh)	HA ($/MWh)		RT-25% ($/MWh)	RT-Low ($/MWh)
Congested	55	186		112	
UnCongested	50	94		108	92

11.2. Average Prices for SP15 Load

Table B2, Average Prices for SP15 Load for Path 15 congestion analysis

SP15 Load	DA Average Price ($/MWh)	HA Average Price ($/MWh)
Congested	43.4	124
UnCongested	52.8	114.3

11.3. Comparison of Real-time Costs for SP15 Load

In Table B3, we break down the costs to those associated with the over scheduled and under-scheduled hours. We see that although the two overall unconstrained (uncongested) real-time costs are roughly the same, the costs with the under and over-scheduling change.

Table B3, **Congested** and **UnCongested** MWhs of SP15 PX Load for Path 15 congestion analysis with the RT load separated in positive and negative imbalance

SP15 Load	RT Quantities (1000 MWh)		RT-25% Cost (Millions)	RT-Low Cost (Millions)
Congested				
MWh > 0	539	62.1		
MWh <= 0	-1,446	-39.6		
Totals	**-907**	**22.5**		
UnCongested				
MWh > 0	767		81.8	75.6
MWh <= 0	-1,305		-43	-37
Totals	**-538**		**38.8**	**38.6**

11.4. Real-time prices for SP15 Load

Table B4, Average Prices for SP15 Load for Path 15 congestion analysis

SP15 Load		RT-25% Price ($/MWh)	RT-Low Price ($/MWh)
Congested			
MWh > 0	115		
MWh <= 0	27.4		
UnCongested			
MWh > 0		107	98.6

MWh <= 0		32.9	28.4